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EVALUATING SPRUCE MORTALITY USING AERIAL INFRARED 70 MM PHOTOGRAPHY IN THE WHITE MOUNTAINS, ARIZONA

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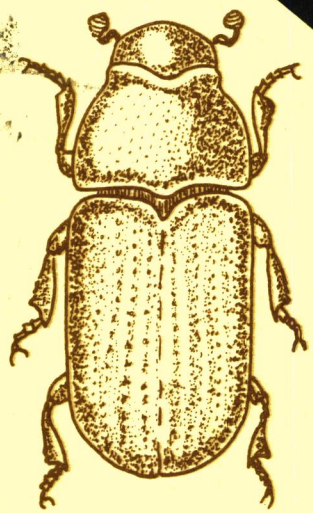

Southwestern Region

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EVALUATING SPRUCE MORTALITY USING AERIAL INFRARED 70 MM PHOTOGRAPHY IN THE WHITE MOUNTAINS, ARIZONA

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1977

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INTRODUCTION

The largest concentration of commercial spruce forests in Arizona is found in the White Mountains. Extensive infestations in the White Mountains occurred from 1948-53 and 1967-71. An estimated 22 percent (8.4 MMBF) of the remaining spruce resource was killed by the spruce beetle in Smith, Paradise, Diamond, and Ord Creek drainages by 1971 (Acciavatti 1972).

The need to assess the damage caused by the spruce beetle was recognized in 1972. A national effort to obtain data on resource impact by damaging forest insects was undertaken. Region 3 was given the task of determining the impact on the spruce resource caused by this insect.

Extensive ground surveys were conducted in the White Mountains from 1969 to 1972 to measure damage. Two more years of data were collected in 1973 and 1974, but all of these data provided only a general indication of spruce beetle damage in the White Mountains. To obtain information on stand depletion and recovery, a continuing study was begun in 1975 (Acciavatti 1976). Two 300-acre study areas were established in Bonito and West Fork drainages to evaluate spruce beetle impact on timber resource management.

The Western Forest Insect Issues Study in 1976 re-enforced the need to obtain reliable estimates of tree mortality over large, often inaccessible, acreages of forest land. Field surveys to obtain these estimates in these areas had proven to be too costly and impractical. Standard aerial detection surveys could provide basic information as to extent and location of tree mortality, but not an estimate of dead stems per acre. Wear et al. (1966), Klein (1973, 1974, 1975, and 1976), and Ciesla et al. (1967) showed that relatively low-cost aerial photographic surveys also could provide accurate estimates of dead stems per acre. The purpose of this report is to present the results of an aerial photographic survey to estimate damage caused by the spruce beetle.

OBJECTIVES

In 1975, an evaluation was made to determine the feasibility of measuring standing spruce mortality using aerial infrared 70 mm photography in the White Mountains, Arizona (Fig. 1). This was a preliminary evaluation designed to test:

1. The feasibility of using 70 mm aerial infrared photography in spruce beetle damage assessment.

2. A newly designed camera mount (Fig. 2).

3. The feasibility of using trained versus untrained interpreters to evaluate photo plots (Fig. 3). The results of this evaluation are presented in this report.

METHODS

The sample area was limited to a 300-acre rectangular plot, established by Acciavatti (1976) for damage assessment, in Bonito Creek (Fig. 4).

Double sampling technique was used in this evaluation. The technique employes an aerial photographic and interpretation phase, and a ground truth phase. In the ground truth phase, a subsample of the photo plots is surveyed (100%) to determine the actual number of dead trees on those plots.

A regression estimator, using linear regression analysis between photo interpretation data and ground truth data, was used to provide a corrected estimate of dead trees per acre over the entire 300-acre survey area.

Aerial Photograph Phase

The aerial photographic phase was conducted on October 16, 1975. The aerial platform consisted of a Cessna 206 aircraft equipped with a 70 mm Hasselblad EL/M camera, a 250 mm lens, and Wratten 12 filter equivalent, using Kodak 2443 infrared aerial film. The photo scale was 1:2,250 feet.

An aerial camera mount for the Hasselblad was designed and constructed by the Region 3, Forest Insect and Disease Management aerial survey specialist, E. T. Wilson, and the Region 6 remote sensing specialist, John F. Wear. The camera mount is secured to the floor of the aircraft with Barry shock mounts. The Barry shock mounts also eliminate aircraft vibration. A 4-inch hole in the floor and an 8-inch hole in the skin of the aircraft accommodate the camera mount adequately. Aircraft drift can be corrected from 0 to 20° (in 5-degree increments) in either direction.

Interpretation Phase

The photo plots were delineated on 70 mm infrared color transparencies, and spruce mortality for each plot was recorded. Five individuals, using a Bausch and Lomb 240Z stereoscope mounted on a Richards light table, interpreted the film. This method enables the interpreter to enlarge the film image optically to the optimum degree of resolution. A total of 48 (0.25 acre) stereo photo plots were interpreted (4% of the 300-acre survey area).

Ground Truth Phase

The ground truth phase was conducted on June 15-17, 1976. Five ground truth plots (10.4%) were selected for examination. Resource photography (1:15,840) was used for ground orientation in locating photo plots. A

hand-held stereo viewer, with an independent light source, was used to view the photo plots in the field for establishing plot boundaries. A clinometer and a 100-foot tape were used to measure one side of the plot boundaries of ground plots. Plot corners were staked, and string was used to delineate plot boundaries. All standing spruce mortality within plots was recorded as spruce beetle-killed trees (old) or cause of mortality unknown (snag). Diameter measurements were also taken.

RESULTS AND DISCUSSION

Excessive winds on the day of the photo mission caused plot placement to be concentrated in the northwest half of the 300-acre survey area (Fig. 4). Clumping of plots caused problems in establishing photo plots on the film. The original planned $\frac{1}{2}$-acre square plots had to be changed to $\frac{1}{4}$-acre rectangular plots to provide stereo viewing. The camera mount performed exceptionally well. The effects of aircraft vibration were reduced to insignificant levels while allowing for correction of aircraft crab.

Of the 5 photo interpreters, interpreters 1 and 2 were proficient at photo interpretation, while 3, 4, and 5 had no previous experience with color infrared photo interpretation. The number of dead spruce trees per plot for all 48 plots for each interpreter is given in Table 1. Plot variability between interpreters ranged from (C.V.) 4 to 34 percent. Interpreters had the most difficulty with plot #2 because of the large number of snags; 35 percent were snags.

The number of dead spruce trees for the five ground truth plots are compared with these same five photo sample plots as given in Table 2. Ground truth plots confirmed the photo scale at 1:2,250 $\pm$ 45 feet (2%).

Regression lines were constructed for each of the 5 photo interpreters, comparing photo plot interpretation against actual ground truth (Fig. 5-9). An F-test was used to test the fit of the data to these regression lines. Interpreters 1 and 2 showed excellent agreement between the photo and ground truth plots ($P < 0.01$). Their r-values were .96 and .97, respectively. Interpreter 4 showed good agreement between the photo and ground truth plots ($P < 0.05$) ($r = .89$). Interpreters 3 and 5 showed no agreement between the photo and ground truth plots ($P < 0.05$). Their r-values were .84 and .87, respectively.

The adjusted dead spruce trees per acre for the 300-acre survey area for each interpreter, using the regression estimator, are given in Table 3. Corrected trees per acre ranged from 66.24 to 83.24--a difference of 17.0 trees per acre. This variation, in part, may

be due to the limited sample size for ground truth used to establish the linear relationship. The effects of the limited sample size are reflected in the confidence limits placed on the estimate of trees per acre for each interpreter. These estimates and confidence limits for each interpreter are tabulated below:

Interpreter	Estimate of trees/acre
1	77.88 ± 17.13
2	75.60 ± 15.57
3	83.24 ± 27.74
4	80.16 ± 24.69
5	66.24 ± 34.90

These data are in disagreement with those obtained by Acciavatti (1976) in Bonito Creek. He found the average number of spruce beetle-killed trees per acre to be 39 + 7. Two factors contribute to this difference. First, Acciavatti (1976) did not count snags on his plots, where in the aerial photo evaluation, snags were not discriminated against in the photo interpretation phase. Snags on the five ground truth plots did account for 25 percent of the dead spruce trees. The actual percentage of snags per acre is unknown, as the five ground truth plots cover only 0.4 percent of the total study area. Second, aerial photo plots were concentrated in the northwest half of the 300-acre survey area. In this area, the trees per acre average about 50, and in the southeast half about 30.[1/] Allowing for a 25 percent increase in dead trees due to snags in the northwest half of the survey, the number of dead trees per acre could approach 50 + .25(50) or 62.5. This estimate more closely approaches the estimate obtained in this study.

CONCLUSIONS

This study clearly demonstrates the feasibility of using 70 mm aerial infrared photography in spruce beetle damage assessment. Good agreement between photo plots and ground truth plots was obtained by 3 of the 5 photo interpreters (P.I.'s 1, 2, & 4). It also demonstrates that, with minimal training, unskilled interpreters are capable of performing at or near the 95 percent confidence level.

A number of problems surfaced in this initial evaluation. Most of these problems can be tied back to a single source--photo overlap. Because of insufficient photo overlap, the originally planned $\frac{1}{2}$-acre square plots were reduced to $\frac{1}{4}$-acre rectangular plots. This produced a border effect on the plots. That is, the $\frac{1}{4}$-acre plots had a higher

1/ Raw data provided by Acciavatti.

border-area ratio (1.5) than the planned $\frac{1}{2}$-acre plots (1.0). This means that an interpreter had more border trees to contend with and, consequently, had more decisions to make to determine if a particular tree was in or out of the plot. Hence, increased variability between interpreters.

A second prime source of variation between observers involved the presence of snag trees on the plots. These are trees, probably dead for more than 10 years, which show as a point source on the stereo photos. They are sometimes, but not always, given away by the shadow cast by the main bole of the tree. Snags posed the biggest identification problem to the untrained interpreters.

Increasing the number of ground truth plots will increase the reliability of the regression estimator.

No problems were encountered with the newly designed camera mount. Camera vibration and aircraft "crab" are two major obstacles in a photo mission. The new mount reduced camera vibration to insignificant levels, while allowing for correction of aircraft crab. Some crab was noticeable on the photos, but posed no problem in the photo interpretation phase.

Future photo missions will be designed with these problems in mind. The main problem of insufficient photo overlap is a technical problem which is easily solved. Identification of snag trees comes with experience.

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Table 1.--No. of dead spruce trees per plot per photo interpreter.

Plot #	Photo interpreter				
	1	2	3	4	5
1	24	27	22	17	26
2	14	12	13	10	20
3	25	23	23	23	24
4	22	19	18	18	23
5	29	23	28	25	28
6	20	15	15	19	17
7	18	14	15	15	17
8	13	11	9	11	13
9	32	30	32	31	25
10	31	30	21	25	26
11	24	19	15	19	23
12	13	13	10	9	13
13	14	15	8	13	16
14	11	10	9	9	10
15	7	7	6	6	8
16	15	14	12	16	14
17	10	8	8	11	14
18	13	11	11	9	17
19	20	18	19	22	19
20	30	25	20	24	31
21	22	19	17	19	22
22	21	20	17	18	19
23	24	21	20	19	28
24	27	26	21	22	25
25	10	10	8	8	12
26	14	13	13	11	13
27	25	23	24	19	25
28	22	27	19	21	23
29	25	23	25	28	24
30	9	7	6	14	11
31	13	12	12	10	13
32	19	22	18	14	20
33	16	13	10	14	16
34	27	24	23	22	24
35	16	16	12	14	19
36	18	14	13	14	18
37	12	10	11	12	13
38	7	7	9	10	8
39	22	19	19	21	25
40	14	11	13	11	13
41	11	13	13	11	15
42	8	7	6	6	9

Table 1.--No. of dead spruce trees per plot per photo interpreter (continued).

Plot #	Photo interpreter				
	1	2	3	4	5
43	19	22	16	22	23
44	17	13	10	18	15
45	18	18	19	17	19
46	16	15	16	16	18
47	6	3	6	4	8
48	7	6	8	6	8
Total trees per plot	850	778	718	753	870
$\bar{x}_1$	17.7	16.2	15.0	15.7	18.1

Table 2.--No. of dead spruce trees per plot for ground truth and photo interpretation.

Plot #	Ground truth	Photo interpreter					C.V. %
		1	2	3	4	5	
2	17	14	12	13	10	20	27
9	32	32	30	32	31	33	10
10	32	31	30	21	25	26	15
21	20	22	19	17	19	22	11
43	22	19	22	16	22	23	14
$\bar{x}_2$		23.6	22.6	19.8	21.4	24.8	
$\bar{y}_2$	24.6						

Table 3.--Corrected trees per acre.

	Photo interpreter				
	1	2	3	4	5
$\bar{x}_1$ - mean[1/] tree count on all 48 plots	17.7	16.2	15.0	15.7	18.1
$\bar{x}_2$ - mean[2/] tree count on 5 plot photo sample	23.6	22.6	19.8	21.4	24.8
$\bar{y}_2$ - mean[2/] tree count on 5 plot ground truth	24.6	24.6	24.6	24.6	24.6
regression[3/] equation $\hat{y}=a+bx$	$\hat{y}=4.13+.87x$ r=.96	$\hat{y}=4.59+.89x$ r=.97	$\hat{y}=8.89+.79x$ r=.84	$\hat{y}=7.41+.80x$ r=.89	$\hat{y}=5.22+1.20x$ r=.87
yrd = adjusted mean tree count $\bar{y}_2+b(\bar{x}_1-\bar{x}_2)$	19.47	18.90	20.81	20.04	16.56
Trees per acre 4xyrd	77.88	75.60	83.24	80.16	66.24

1/ From Table 1.
2/ From Table 2.
3/ Fit for regression equations for P.I.'s 1 and 2 are significant at 1%; for P.I. 4 at 5%; and for P.I.'s 3 and 5, not significant.

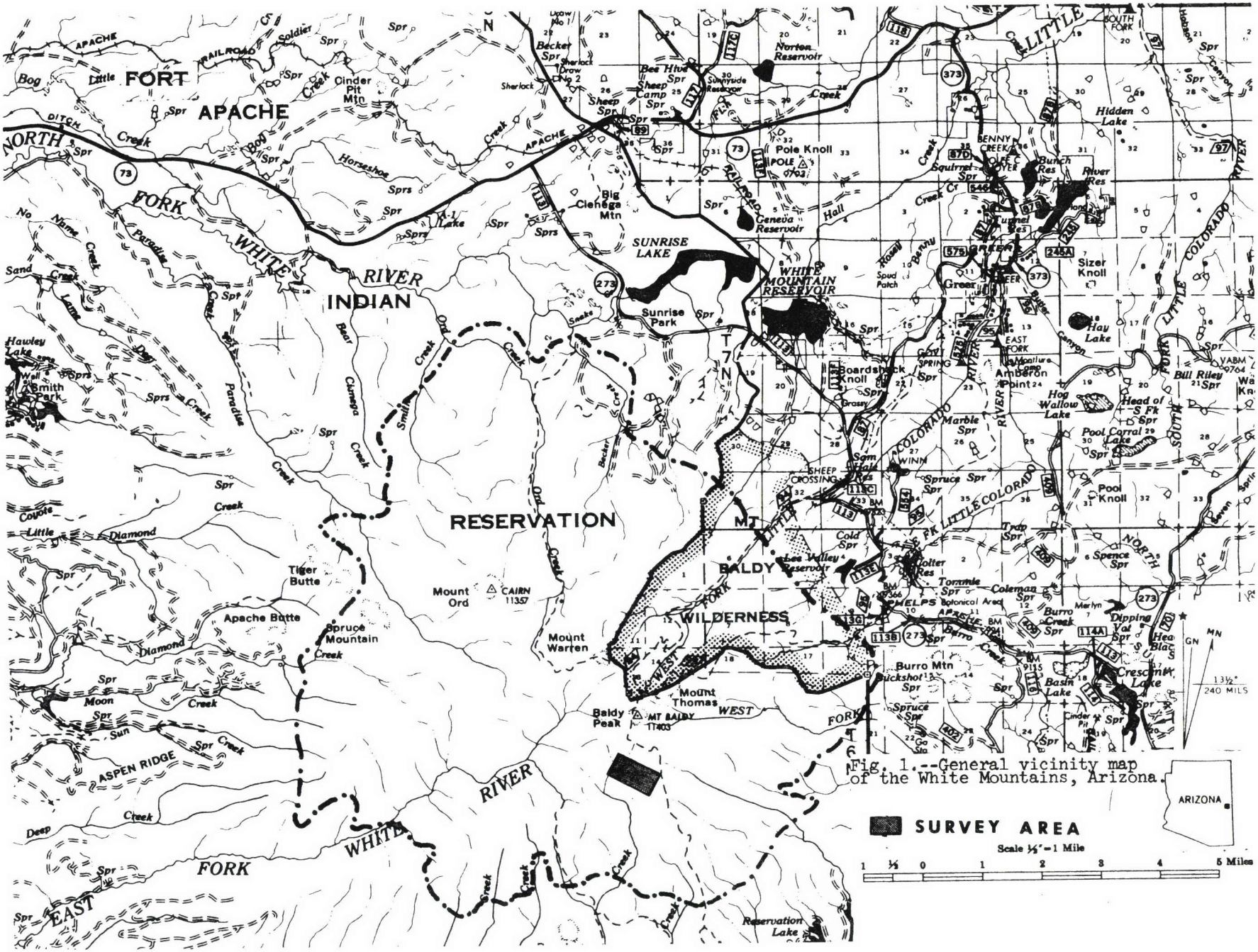

Fig. 1.--General vicinity map of the White Mountains, Arizona.

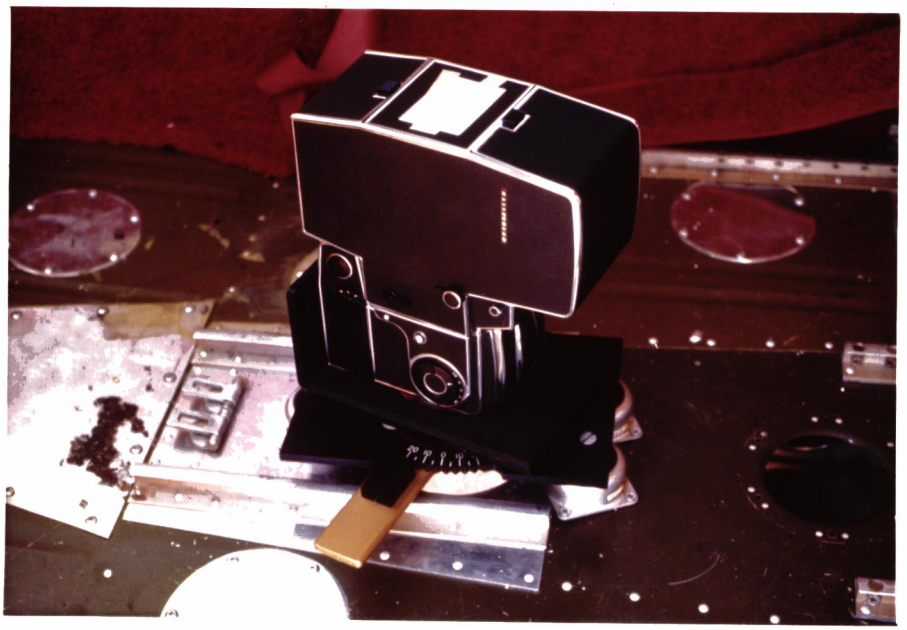

Fig. 2.--Aerial camera mount designed for the Hasselblad EL/M camera.

Fig. 3.--Photo interpretation using the Bausch and Lomb 240Z stereoscope mounted on a Richards light table.

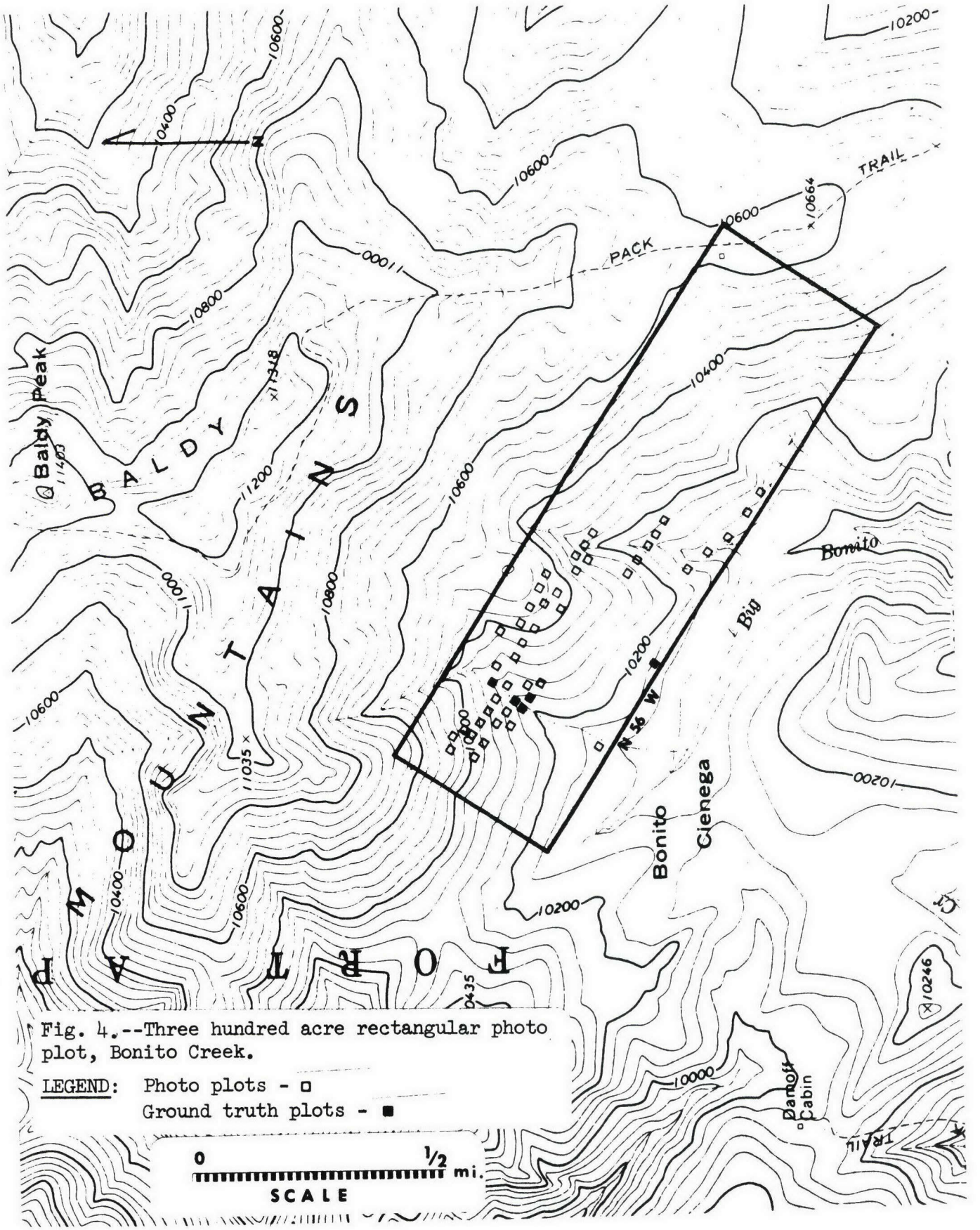

Fig. 4.--Three hundred acre rectangular photo plot, Bonito Creek.

LEGEND: Photo plots - □
Ground truth plots - ■

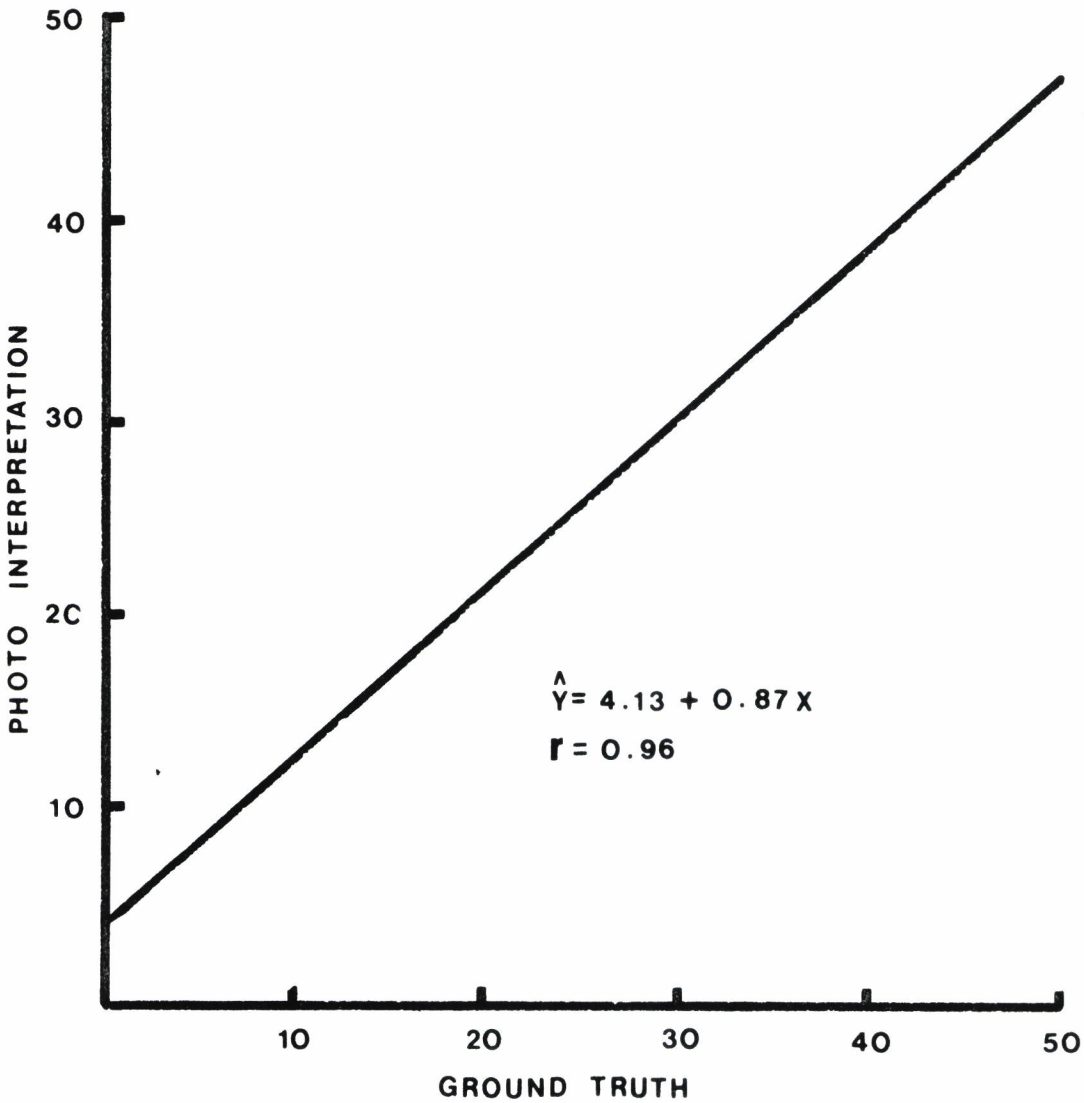

Fig. 5.--Photo interpreter number 1. Number of trees per quarter acre photo interpretation as a function of ground truth.

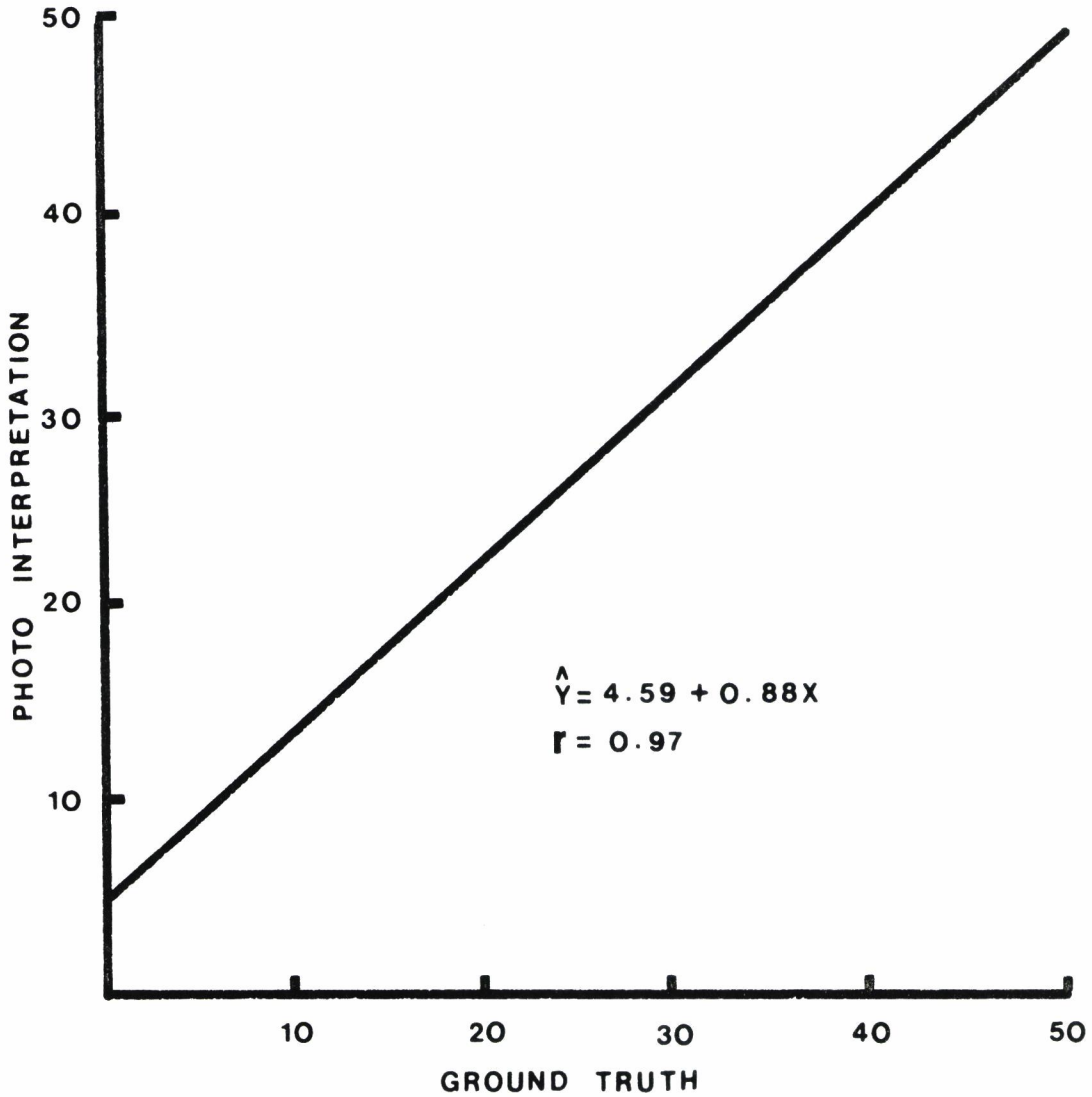

Fig. 6.--Photo interpreter number 2. Number of trees per quarter acre photo interpretation as a function of ground truth.

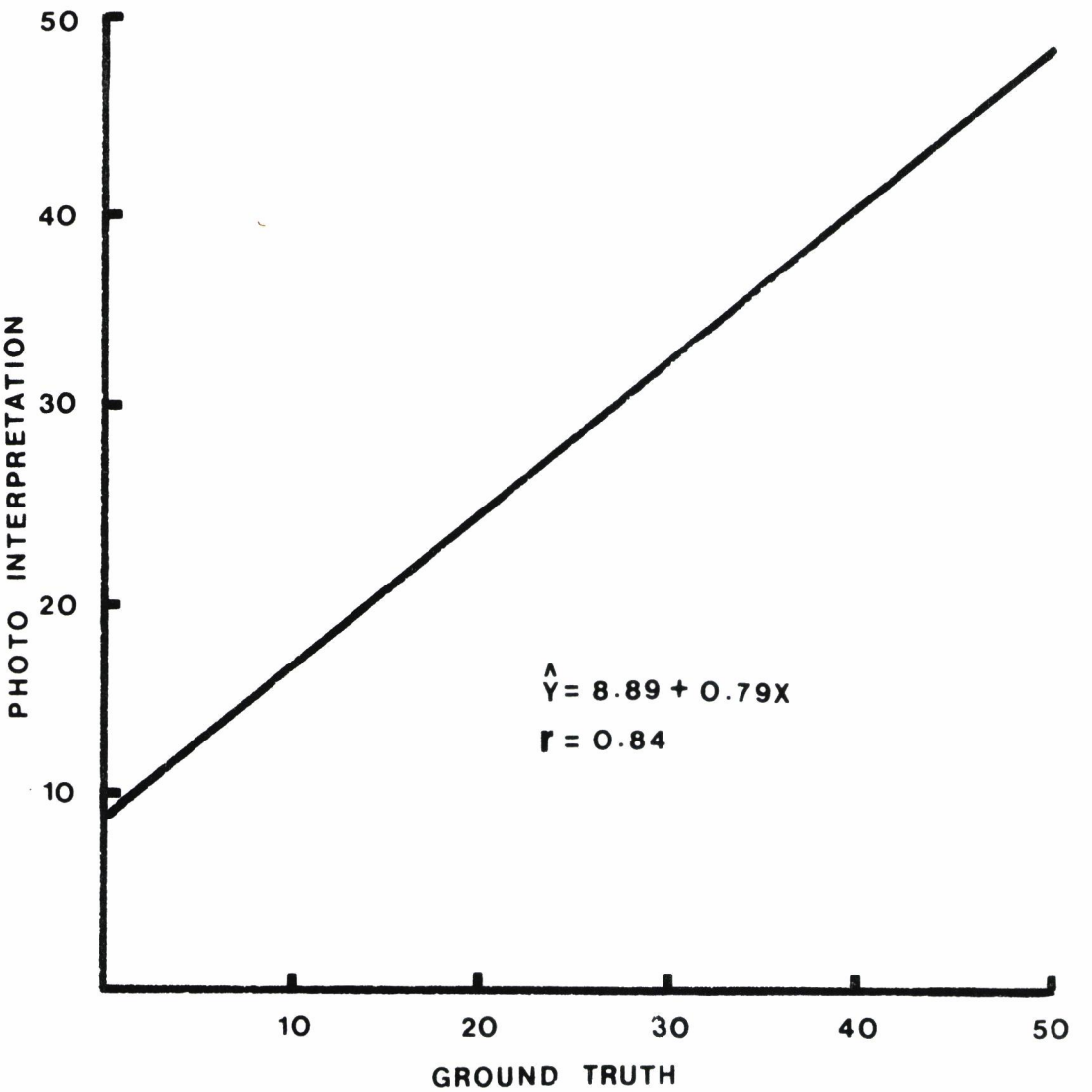

Fig. 7.--Photo interpreter number 3. Number of trees per quarter acre photo interpretation as a function of ground truth.

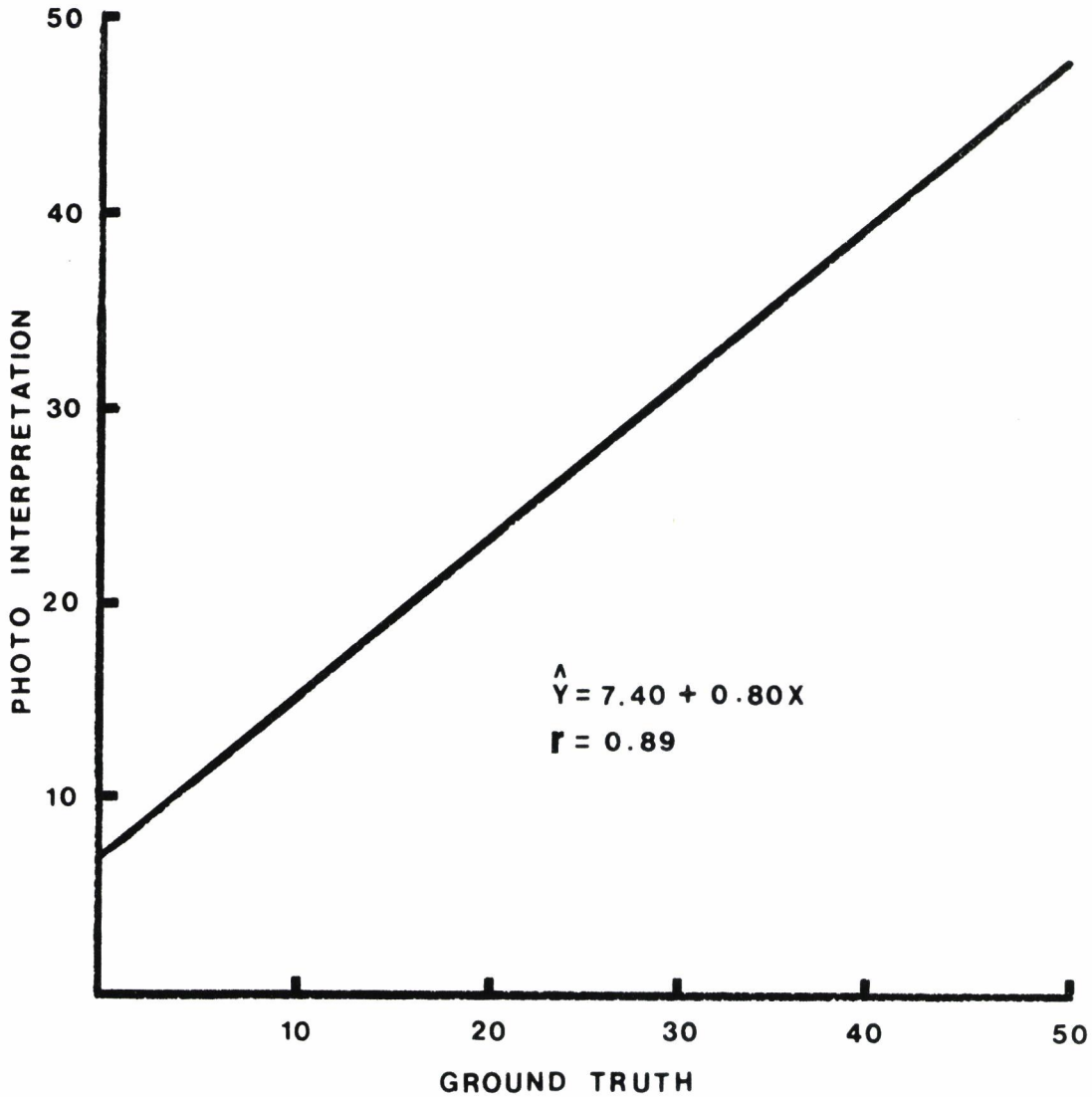

Fig. 8.--Photo interpreter number 4. Number of trees per quarter acre photo interpretation as a function of ground truth.

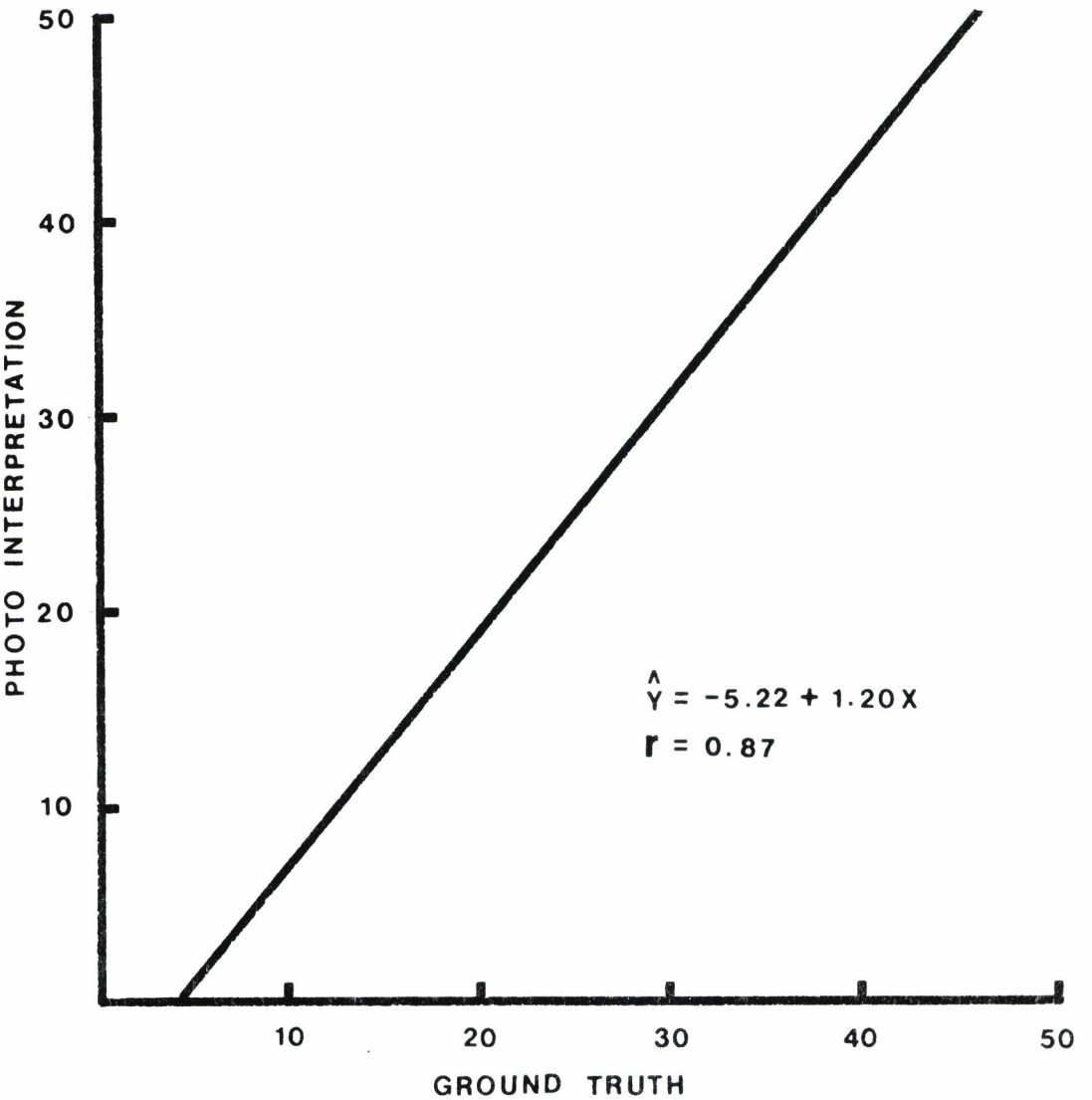

Fig. 9.--Photo interpreter number 5. Number of trees per quarter acre photo interpretation as a function of ground truth.